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APPLICATION FOR LETTERS PATENT

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Methods Of Forming Capacitors And Resultant Capacitor Structures

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INVENTOR

Alan R. Reinberg

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METHODS OF FORMING CAPACITORS AND RESULTANT CAPACITOR STRUCTURES

TECHNICAL FIELD

The present invention relates to methods of forming capacitors and to resultant capacitor structures.

BACKGROUND OF THE INVENTION

As integrated circuitry dimensions continue to shrink, challenges are posed with respect to the techniques through which integrated circuit structures are formed. For example, with very small device dimensions, unwanted conductive particles present during fabrication can cause undesired shorting should they come into contact with, and not be adequately removed from integrated circuitry being formed. One type of integrated circuit structure is a capacitor. Such capacitors are typically used in dynamic random access memory circuitry. Undesired shorting can take place if such conductive particles are allowed to undesirably contact the capacitor storage nodes of such capacitors.

Accordingly, this invention arose out of concerns associated with providing improved methods of forming integrated circuitry which reduce the risk of undesired particles shorting the resultant integrated circuitry structures. In particular, this invention arose out of concerns associated with providing improved methods of forming capacitors, and resultant capacitor constructions.

1 SUMMARY OF THE INVENTION

2 Methods of forming capacitors and resultant capacitor structures
3 are described. In one embodiment, a capacitor storage node layer is
4 formed over a substrate and has an uppermost rim defining an opening
5 into an interior volume. At least a portion of the rim is capped by
6 forming a material which is different from the capacitor storage node
7 layer over the rim portion. After the rim is capped, a capacitor
8 dielectric region and a cell electrode layer are formed over the storage
9 node layer.

10 In another embodiment, a capacitor storage node layer is formed
11 within a container which is received within an insulative material. A
12 capacitor storage node layer is formed within the container and has an
13 outer surface. A layer of material is formed within less than the entire
14 capacitor container and covers less than the entire capacitor storage
15 node layer outer surface. The layer of material comprises a material
16 which is different from the insulative material within which the capacitor
17 container is formed. After the capacitor storage node layer and the
18 layer of material are formed, a capacitor dielectric functioning region
19 is formed which is discrete from the layer of material and operably
20 proximate at least a portion of the capacitor storage node layer outer
21 surface. A cell electrode layer is formed over the dielectric functioning
22 region and the layer of material.

23 In another embodiment, a capacitor container is formed within an
24 insulative material over a substrate. A capacitor storage node is formed

1 within the container and has an uppermost surface and a side surface
2 joined therewith. A protective cap is formed over the uppermost
3 surface. A dielectric layer is formed over at least some of the side
4 surface and protective cap. A cell electrode layer is formed over the
5 side surface of the capacitor storage node.

6 7 BRIEF DESCRIPTION OF THE DRAWINGS

8 Preferred embodiments of the invention are described below with
9 reference to the following accompanying drawings.

10 Fig. 1 is a diagrammatic side sectional view of a semiconductor
11 wafer fragment undergoing processing in accordance with one
12 embodiment of the invention.

13 Fig. 2 is a view of the Fig. 1 wafer fragment at a processing
14 step which is different from that which is shown in Fig. 1.

15 Fig. 3 is a view of the Fig. 1 wafer fragment at a processing
16 step which is different from that which is shown in Fig. 2.

17 Fig. 4 is a view of the Fig. 1 wafer fragment at a processing
18 step which is different from that which is shown in Fig. 3.

19 Fig. 5 is a view of the Fig. 1 wafer fragment at a processing
20 step which is different from that which is shown in Fig. 4.

21 Fig. 6 is a view of the Fig. 1 wafer fragment at a processing
22 step which is different from that which is shown in Fig. 5.

23 Fig. 7 is a view of the Fig. 1 wafer fragment at a processing
24 step which is different from that which is shown in Fig. 6.

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1 Fig. 8 is a view of the Fig. 1 wafer fragment at a processing
2 step which is different from that which is shown in Fig. 7.

3 Fig. 9 is a view of the Fig. 1 wafer fragment at a processing
4 step which is different from that which is shown in Fig. 8.

5 Fig. 10 is a view of the Fig. 1 wafer fragment at a processing
6 step which is different from that which is shown in Fig. 9.

7 Fig. 11 is a somewhat enlarged view which is taken along 11-11
8 in Fig. 10.

9 10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

11 This disclosure of the invention is submitted in furtherance of the
12 constitutional purposes of the U.S. Patent Laws "to promote the
13 progress of science and useful arts" (Article 1, Section 8).

14 Referring to Fig. 1, a semiconductor wafer fragment in process is
15 shown generally at 20 and includes a semiconductive substrate 22. In
16 the context of this document, the term "semiconductive substrate" is
17 defined to mean any construction comprising semiconductive material,
18 including, but not limited to, bulk semiconductive materials such as a
19 semi-conductive wafer (either alone or in assemblies comprising other
20 materials thereon), and semiconductive material layers (either alone or
21 in assemblies comprising other materials). The term "substrate" refers
22 to any supporting structure, including, but not limited to, the
23 semiconductive substrates described above.
24

1 Substrate 22 includes a plurality of isolation regions 24 which can
2 be formed through known techniques such as trench and refill
3 techniques. Between isolation regions 24 are defined active areas 26
4 which have diffusion regions (undesignated) received therein and which
5 constitute node locations with which electrical communication is desired.
6 Conductive material plugs or studs 28 can be provided by forming a
7 conductive material, such as polysilicon, over the substrate and suitably
8 recessing it relative to insulative material structures 30. An exemplary
9 insulative material is borophosphosilicate glass (BPSG). An insulative
10 layer 32 can be provided as through decomposition of TEOS. A
11 plurality of conductive lines 34 are provided and include conductive
12 portions 36 and insulative portions 38. Conductive portion 36 can
13 comprise polysilicon or polysilicon and a refractory metal layer, or any
14 other suitable material. Insulative portion 38 can comprise any suitable
15 insulative material. Sidewall spacers 40 are also provided and are
16 anisotropically etched as is known.

17 An insulative material layer 42 is formed over substrate 22 and
18 preferably has a generally planar outer surface 44. For purposes of the
19 ongoing discussion, layer 42 constitutes a first material or a container-
20 defining material, with an exemplary material comprising BPSG. A
21 plurality of capacitor containers 46 are patterned and etched, or
22 otherwise formed over substrate 22 and received within insulative
23 material layer 42.
24

1 Referring to Fig. 2, a capacitor storage node layer 48 is formed
2 over substrate 22. Typically, such layer is formed by forming a
3 conductive layer over the substrate and within the capacitor opening,
4 and then planarizing the layer relative to outer surface 44 to electrically
5 isolate individual storage nodes within their respective containers.
6 Planarization of the conductive layer can take place through techniques
7 such as chemical mechanical polishing (CMP). Different types of
8 conductive material can be used to form the storage node layers. In
9 the illustrated and preferred embodiment, layer 48 comprises roughened
10 polysilicon with hemispherical grain (HSG) polysilicon being but one
11 example. Each of the storage node layers 48 define an individual
12 interior volume 50. Preferably, prior to planarizing the conductive layer
13 to electrically isolate the individual storage node layers, a filler or filling
14 material 52 is provided into interior volume 50. This material ensures
15 that the isolation techniques which are utilized to isolate the capacitor
16 storage node layers (e.g. chemical mechanical polishing) do not dislodge
17 conductive material into the interior volume within the containers. An
18 exemplary material for material 52 is a polymer material such as
19 photoresist and the like.

20 Referring to Fig. 3, amounts of both capacitor storage node
21 layer 48 and filler material 52 are removed. In the illustrated example,
22 an amount of storage node layer material corresponding to distance "a"
23 has been removed, and an amount of filler material 52 corresponding
24 to distance "a"+"b" has been removed. In this example, "a" is equal

1 to about 100 Angstrom, and "b" is equal to from between about 100
2 to 750 Angstrom, with about 500 Angstrom being preferred. Removal
3 of the amounts of the capacitor storage node layer and the filler
4 material can take place through a single etch. Such etch would
5 preferably be highly selective to the material from which layer 42 is
6 formed, e.g. BPSG, while etching material 52 at a somewhat faster rate
7 than the material from which the storage node layer is formed.
8 Alternately, an etch of one of materials 48 and 52 can be conducted
9 first, followed by an etch of the other of the materials 48 and 52.
10 While both wet and dry etches can be utilized, dry etches are
11 preferred. For example, and where material 48 comprises HSG
12 polysilicon and material 52 comprises a polymer such as photoresist, a
13 first etch of the polysilicon can be conducted using a chemistry
14 including CF_4 with from between 2% to 10% O_2 . This etch can be
15 used to etch the polysilicon principally with a high selectivity to
16 the BPSG, e.g. greater than about 20:1. Subsequently, the polymer can
17 be etched selective to the BPSG and polysilicon by using an oxygen-
18 containing etch such as one with constituents such as O_2 , N_2O ,
19 and CO_2 .

20 As shown in Fig. 3, capacitor storage node layer 48 includes an
21 outer surface comprising an outside surface 54, an uppermost surface 56
22 joined with outside surface 54, and an inside surface 58 joined with
23 uppermost surface 56. Uppermost surface 56 provides an uppermost
24 rim which defines an opening into interior volume 50. Inside

1 surface 58 is spaced inwardly from outside surface 54, with both
2 surfaces (both of which constitute side surfaces) extending away from
3 the node location defined by active areas 26. The outside and inside
4 surfaces terminate proximate an opening into an interior region, i.e.
5 interior volume 50. Preferably, portions of capacitor storage node
6 layer 48 are removed which are sufficient to recess the capacitor
7 storage node layer to below generally planar outer surface 44.
8 Accordingly, uppermost surface 56 is disposed elevationally below
9 generally planar outer surface 44. A portion of container 46 is filled
10 with filling or filler material 52 sufficiently to provide a filling material
11 upper surface 60 disposed elevationally below uppermost surface 56 of
12 capacitor storage node layer 48. Accordingly, such constitutes partially
13 filling the capacitor container with filler material. Accordingly, less than
14 the entire interior volume 50 is filled with filler material.

15 Referring to Fig. 4, a material layer 62 is formed over
16 substrate 22 and over or atop fill material upper surface 60.
17 Preferably, a portion of the layer is formed to contact the storage node
18 layer. For purposes of the ongoing discussion, layer 62 constitutes a
19 second material. Preferably, and for reasons which will become
20 apparent below, material 62 is selected to be a material which is
21 different from, and one which can be etched slower relative to material
22 from which layer 42 is formed. Additionally, layer 62 preferably
23 comprises a material which can be deposited at a temperature which is
24 lower than the flow temperature of filling material 52. In one

embodiment, layer 62 comprises an insulative material which is formed over the substrate and within less than an entirety of interior volume 50. Preferably, layer 62 is formed over filler material 52 as well. In another embodiment, layer 62 is formed within less than the entire capacitor container and covers less than the entire capacitor storage node layer outer surface. Where, as here, layer 42 has been described to comprise BPSG, a suitable material for material 62 is oxygen-doped, PECVD amorphous silicon. Such exemplary material can be deposited by combining silane gas with N_2O , O_2 , or CO_2 . Another preferred material is a co-called DARC material, i.e. a dielectric/deposited anti-reflective coating, to produce a SiO_xN_y material. Of course, other dielectric materials, and other materials can be used.

Referring to Fig. 5, portions 60a of the upper surface of filling material 52 are exposed by removing portions of layer 62. In this manner, the opening is redefined as a narrower opening which, in this example, exposes exposed portions 60a of filler material 52. In one embodiment, removal of the material layer portions is sufficient to cap at least a portion of rim 56. In another embodiment, encasement structures 64 are formed from layer 62 over an uppermost portion of the storage node layer outer surface. Such defines, in one embodiment, a protective cap over uppermost surface 56. In a preferred embodiment, the encasement structure or protective cap 64 is also formed over a portion of one of the side surfaces of the capacitor storage node. In the illustrated and preferred embodiment, a portion

1 of inside surface 58 is covered with material of the encasement
2 structure or protective cap. In another embodiment, encasement
3 structure or protective cap 64 comprises a dielectric cap which is
4 formed within the opening of each capacitor container and covers less
5 than an entire portion of inside surface 58. Preferably, formation of
6 the encasement structure or protective cap takes place through
7 anisotropic etching of layer 62. The etching is, in one embodiment,
8 sufficient to leave a portion of the material occluding the opening and
9 preferably extending into the interior volume. An exemplary etch
10 chemistry consists of fluorocarbon and hydrofluorocarbon gas mixtures.

11 Referring to Fig. 6, and in accordance with one embodiment, filler
12 material 52 (Fig. 5) is removed from within capacitor containers 46.
13 In the illustrated example, such constitutes removing filling material from
14 elevationally below material layer 62. Such can take place through the
15 use of conventional techniques such as O_2 plasma.

16 Referring to Fig. 7, and after capping rim portion 56, at least
17 some of the container-defining material or insulative material 42 (Fig. 6)
18 is removed. In a preferred embodiment, the removal of the container-
19 defining material takes place by selectively removing the material relative
20 to capping material 62. Accordingly, such constitutes, in the preferred
21 embodiment, selectively removing insulative material relative to material
22 from which the protective cap is formed. Alternately considered, such
23 constitutes removing material of the first material selectively relative to
24 material of the second material. In one embodiment, the removal of

material 42 can take place through a timed etch. Where layer 42 comprises BPSG, and material 62 comprises SiO_xN_y , an exemplary etch can include a combination of acetic acid and hydrofluoric acid. A more specific chemistry is as follows: Acetic acid:HF:H₂O in ratio 10:1:1 used at a temperature of 50°C.

Referring to Fig. 8, a capacitor dielectric region 66 is formed over capacitor storage node layer 48. In one embodiment, such constitutes forming a capacitor dielectric functioning region which is discrete from material layer 62 comprising the protective cap over each storage node layer. The capacitor dielectric functioning region is disposed operably proximate at least a portion of the capacitor storage node layer outer surface (i.e., outside surface 54, uppermost surface 56, and inside surface 58). Accordingly, and in a preferred embodiment, the capacitor dielectric layer or dielectric functioning region is formed over at least some of one of the side surfaces, and preferably at least some of both of the side surfaces.

Referring to Fig. 9, a cell electrode layer or cell plate layer 68 is formed over the substrate and preferably portions of capacitor storage node layer 48. Accordingly, cell electrode layer 68 is formed over the dielectric functioning region 66 and the protective cap formed from material layer 62.

Referring to Fig. 10, an insulative material layer 70, e.g. BPSG, is formed over substrate 22 with subsequent processing taking place through known techniques.

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1 over uppermost surface 56. That portion is elevationally thicker than
2 the relatively thin dielectric functioning region 66.

3 Advantages of the inventive methods and structures include that
4 problems associated with container-to-container shorts from particles
5 residing on the top of the cells connecting two adjacent cells are
6 mitigated. Such advantages are particularly useful in the context of
7 containers using roughened polysilicon such as HSG polysilicon for the
8 capacitor storage node layers. The inventive methods and structures are
9 even more useful in the context of dual-sided containers having
10 dielectric functioning regions and cell plate layers formed over both
11 inside and outside surfaces.

12 In compliance with the statute, the invention has been described
13 in language more or less specific as to structural and methodical
14 features. It is to be understood, however, that the invention is not
15 limited to the specific features shown and described, since the means
16 herein disclosed comprise preferred forms of putting the invention into
17 effect. The invention is, therefore, claimed in any of its forms or
18 modifications within the proper scope of the appended claims
19 appropriately interpreted in accordance with the doctrine of equivalents.
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